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The System Engineering Model on Evaluating the Symbiosis Situation of Industrial Clusters*

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Abstract

Based on symbiosis theory and principle of system engineering, this paper discussed the symbiosis unit, symbiosis mode and symbiotic environment of industral clusters, built a system engineering model called "cluster and symbiosis degree model" which could be used to evaluate the symbiosis situation between two industral clusters, and carried out an empirical analysis for the symbiosis situation between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen in China. The result shows that the symbiosis situation of Shenzhen's venture capital industrial cluster and high-tech industrial cluster is much better than that of Beijing and Shanghai. This model could be used to evaluate the symbiosis situation of any industrial clusters, which will have important theoretical and practical value to any industrial system.

Keywords: Industrial cluster; clusters' symbiosis; cluster and symbiosis degree; symbiosis coefficient; system engineering

1. Introduction

The concept of "Symbiosis" was firstly proposed by Germany biologist Anion De Bary in 1879, it means that because of the need of survival, different kinds of life-forms depend on each other and interact mutually in some kind of pattern, and form symbiosis relations which contain co-existence and the coordination evolution [1]. The Chinese scholar Yuan Chunqing [2] first defined the concept of "symbiosis", which is the relations symbiosis unit form according to some kind of symbiosis pattern in certain symbiosis environment. Mirata and Emtairah [3] thought that industrial symbiosis implies regional enterprises could form the long-term cooperation symbiotic relationship by physical exchange or the material and energy transmission, and by the exchange of knowledge，human resources and technical resources before it achieves environmental benefits and effectiveness of competition. Bradford [4] started with analyzing the development process of American venture capital industry, and subsequently summarized the symbiotic evolution track of venture capital and biotechnology industry. Avnimelech and Teubal [5] built an industrial life cycle model to analyze the co-evolutionary relationship of Israeli venture capital and high-tech industry. The deep research about "Symbiosis" of scholars such as Surindar and Vernon [6], Angela [7], Jan [8], Lynn and René [9], Kisho Kurokawa [10] had made the theory tend to be mature gradually, and had been widely applied in system engineering and social sciences domains such as anthropology, sociology, economic, management science even politics research and so on.

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There are few research results on evaluating the symbiosis situation between different industries while the authoritative research results are the symbiosis degree model constructed by Yuan Chunqing and the symbiosis coefficient model which transforms by the symbiosis degree model. However, owing to the relative value of computed result instead of the absolute figure, the symbiosis situation evaluation between different industries using symbiosis degree model and symbiosis coefficient model, will neglect the scale of the industries and cannot evaluate the symbiosis situation comprehensively. The author believe that the industrial scale is the basic safeguard of the symbiosis relation between two different industries, we cannot study the symbiosis relation directly with the industrial scale be separated. Therefore, considering both the symbiosis situation and the cluster situation of the two industries, the author has constructed the system engineering model of cluster and symbiosis degree, which is advantageous in evaluating the symbiosis situation of the industrial clusters systematically, scientifically and comprehensively.

2. The rationale of industrial clusters' symbiosis

2.1. The symbiosis unit of industrial clusters

Consulting the definition of "symbiosis" which had be defined by domestic and foreign scholars, this article defined industrial clusters' symbiosis like this, the set of the symbiosis relations which constructed by two different industrial clusters in some region according to certain symbiosis pattern and symbiosis type. The industrial cluster's integrant part (the single enterprise) has formed the symbiosis unit of the industrial clusters.

The symbiosis unit which constructs the symbiosis relation is the basic unit which produces and exchanges the power, and the basic physical condition of the symbiosis system. To understand and descript the symbiosis unit clearly, we need to introduce "Nature parameter" and "Likely parameter" whose combined action has formed the basic power of the existence and the development of the symbiosis unit. The nature parameter refers to the factors which decide the intrinsic property and the change of the symbiosis unit, and the likely parameter refers to the factors which reflect the exterior characteristic of the symbiosis unit. Therefore, we use nature parameter to recognize the symbiosis relation of symbiosis unit. The main nature parameter of industrial clusters symbiosis unit is shown in Table 1.

Table 1. The main nature parameter of symbiosis unit of industrial clusters

	Input			Output	
Nature parameter	y_1	y_2	y_3	y_4	y_5
	Human resources	Capital	Technology	Output value	Profit

Data source: reorganized by authors

2.2. The symbiosis mode of industrial clusters

The symbiosis mode refers to the form which the symbiosis units interact or unify. It reflects the exchange of the matter, information and energy between symbiosis units. There are two kinds of symbiosis modes, one is symbiosis organizational mode, and the other is symbiosis behavior mode. Symbiosis organizational mode can be divided into four modes such as point's symbiosis, intermittent symbiosis, continuous symbiosis and integrated symbiosis, and the integrated symbiosis reflects the strongest correlation degree between the two industries. According to the mobility status of symbiosis energy, symbiosis behavior mode can be divided into parasitism, commensalism, dissymmetrical mutualism symbiosis and symmetrical mutualism symbiosis (see table 2).

Table 2. The classification and character of symbiosis behavior mode of industrial clusters

	Classification	Character
①	Parasitism	One industry cluster to maintain its steady state by consuming the energy of the other industry cluster
②	Commensalism	The benefit produce by the interactions between two industry clusters flows completely to one side
③	Dissymmetrical mutualism symbiosis	The benefit produce by the interactions between two industry clusters flows completely to both sides evenly
④	Symmetrical mutualism symbiosis	The benefit produce by the interactions between two industry clusters flows completely to both sides unevenly

Data source: reorganized by authors

Therefore, the symbiosis mode of two industrial clusters has 16 kind of different combinations, in which symbiosis behavior mode is the core because it manifests the benefit assignment of symbiosis units.

2.3. The symbiosis environment of industrial clusters

The symbiosis relation between the symbiosis units must be produced and promoted in certain environment which called symbiosis environment. The author induced the symbiosis environment of industrial clusters into six aspects, which are the macro- economic environment, the law and policy, the human and culture, the intermediary service, the financial and the talented person. Their functions are as shown in table 3.

Table 3. The classification and functions of symbiosis environment of industrial clusters

	Classification	Functions
①	Macro- economic environment	Provides the background environment support for the healthy development of industrial clusters
②	Law and policy environment	Provides the legal and policy safeguard, the drive and the restraint for the symbiosis behavior of industrial clusters
③	Human and culture environment	Influences the quantity and quality of symbiosis units of industrial clusters
④	Intermediary service environment	Affects the symbiosis efficiency by providing the intermediary service for the symbiosis behavior of industrial clusters
⑤	Financial environment	Provides the convenient channel for the financing of the symbiosis units of industrial clusters
⑥	Talented person environment	Provides the basic guarantee for the long-term development of industrial clusters

Data source: reorganized by authors

3. The construction and the mechanism of the system engineering model on evaluating the symbiosis situation of industrial clusters

3.1. The method and limitation of evaluating the symbiosis situation of industrial clusters by traditional symbiosis theory

(1) Analysis on symbiosis degree model

Supposes the main nature parameter of two industrial clusters A and B is respectively x and y, the formulas to calculate the symbiosis degree model of A and B are as follows.

$$\delta_{AB} = \frac{dx/x}{dy/y} \quad (1)$$

$$\delta_{BA} = \frac{dy/y}{dx/x} \quad (2)$$

In the formulas, δ_{AB} manifests the rate of change of the main nature parameter of industrial cluster A(x) which caused by the rate of change of the main nature parameter of industrial cluster B(y); the meaning of δ_{BA} is opposite to δ_{AB}.

If $\delta_{AB} = \delta_{BA} > 0$, the symbiosis behavior mode between the two industrial clusters is symmetrical mutualism symbiosis in cis direction; if $\delta_{AB} \neq \delta_{BA} > 0$, the symbiosis behavior mode between the two industrial clusters is dissymmetrical mutualism symbiosis in cis direction; if one of δ_{AB} and δ_{BA} is 0, the other is larger than 0, the symbiosis behavior mode between the two industrial clusters is commensalism in cis direction; if one of δ_{AB} and δ_{BA} is 0, the other is smaller than 0, the symbiosis behavior mode between the two industrial clusters is commensalism in trans direction; if $\delta_{AB} = \delta_{BA} < 0$, the symbiosis behavior mode between the two industrial clusters is symmetrical mutualism symbiosis in trans direction; if $\delta_{AB} \neq \delta_{BA} < 0$, the symbiosis behavior mode between the two industrial clusters is dissymmetrical mutualism symbiosis in trans direction.

(2) Analysis on symbiosis coefficient model

Symbiosis coefficient model transforms by the symbiosis degree model, the formulas are as follows.

$$\theta_A = \frac{|\delta_{AB}|}{|\delta_{AB}| + |\delta_{BA}|} \tag{3}$$

$$\theta_B = \frac{|\delta_{BA}|}{|\delta_{AB}| + |\delta_{BA}|} \tag{4}$$

In the formulas, θ_A and θ_B are respectively the symbiosis coefficient of industrial clusters A and B. Obviously, $\theta_A + \theta_B = 1$. If θ_A approaches to 0, it indicates that B nearly does not have any function to A; if θ_A approaches to 1, it indicates that B only has functions to A, and A nearly does not have any function to B; if $0 < \theta_A < 1/2$, it indicates that effect of A on B is greater than that of B on A, vice versa; if $\theta_A = 1/2$, it indicates that effect of A on B is the same as that of B on A, the Symbiosis Behavior mode is mutualism symbiosis (in either cis or trans direction).

Symbiosis degree model and symbiosis coefficient model both manifest the effect of the change of the nature parameter of one industrial cluster on the other. When we use these two models to evaluate the symbiosis situation between different industries, the limitation is the neglect of the effect of the scale of the industrial clusters on the symbiosis situation of the industrial clusters. The following consequences, will be that θ_A and θ_B can still be satisfactory even if the figure of the main nature parameter of industrial cluster A and B are both very small,. Because the main nature parameter of industrial cluster A and B are too little, at this time, θ_A and θ_B cannot manifest the symbiosis relation between A and B.

3.2. The construction of system engineering model of cluster and symbiosis degree

The author believes that it is necessary to consider both the symbiosis degree (or symbiosis coefficient) and the scale of the industrial clusters when the symbiosis situation between different industries is evaluated, no matter how perfect the symbiosis degree (or symbiosis coefficient) is, if the scale of the industrial clusters is not big enough, we cannot say that the symbiosis situation between the two industries is good. If the value of the main nature parameter of the two industrial clusters are too little, even if $\theta_A = \theta_B = 1/2$ (symmetrical mutualism symbiosis), the symbiosis relation of industrial cluster A and B is faint.

To compensate the limitation of symbiosis degree model and symbiosis coefficient model, the author constructs system engineering model of cluster and symbiosis degree to evaluate the symbiosis situation between two industrial clusters, as the formula (5) shows.

$$Z = \left(\frac{x}{T_x}\right)^{w_1} \left(\frac{y}{T_y}\right)^{w_2} \cdot e^{-|\theta_A - \theta_B|} \tag{5}$$

In the formula, Z represents cluster and symbiosis degree, T_x and T_y respectively represent the gross figure of the output value of each industry of the whole nation; w_1 and w_2 are weights, $w_1 > 0$, $w_2 > 0$ and $w_1 + w_2 = 1$.

3.3. The mechanism of system engineering model of cluster and symbiosis degree

Because $|\theta_A - \theta_B| \in [0, 1]$, and $f(x)=e^{-x}$ shows the trend of monotonic decreasing on the interval [0, 1], the function $g(x)= e^{-|\theta_A-\theta_B|}$ gets the maximum value 1 when $\theta_A=\theta_B=1/2$, which ensures that $g(x)$ is much bigger when the symbiosis behaviour mode of industrial cluster A and B is mutualism symbiosis, Cluster and symbiosis degree model combines symbiosis degree with cluster degree can evaluate the symbiosis situation between two industrial clusters comprehensively.

4. Empirical analysis of the model on evaluating the symbiosis situation of industrial clusters

The system engineering model of cluster and symbiosis degree is used in evaluating the symbiosis situation between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen of China. Venture capital management scale is chosen to be the main nature parameter of venture capital industrial cluster and the output value of high-tech industry to be the main nature parameter of high-tech industrial cluster. The initial data as is shown in table 4.

Table 4. The figure of the main nature parameter of venture capital industrial cluster and high-tech industrial cluster

Year	Venture capital management scale (x)				output value of high-tech industry (y)			
	Beijing	Shanghai	Shenzhen	China	Beijing	Shanghai	Shenzhen	China
2003	48.80	32.53	84.59	325.34	1188.5	2258.8	2479.33	20556
2004	100.90	26.32	114.06	438.70	1539.8	3259.74	3266.52	27769
2005	137.68	49.42	77.23	464.50	2134.3	3905.10	4885.26	34367
2006	265.65	91.08	33.86	583.85	2659.9	4473.45	6306.38	41996
2007	443.75	347.28	206.20	1205.85	3186.67	5631.04	7598.76	50461
2008	664.82	288.48	439.26	2506.16	2953.24	5900.90	8714.26	58000

Data source: Yearbook of Chinese venture capital 2009; Yearbook of Chinese high-tech industries 2009; The Department of Science and Technology in Guangdong province

According to data in table 4, we can calculate the symbiosis degree and symbiosis coefficient of venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen of China using formula (1)～(4), which is shown in table 5.

Table 5. The symbiosis degree and symbiosis coefficient of venture capital industrial cluster and high-tech industrial cluster

Year	Beijing				Shanghai				Shenzhen			
	δ_{AB}	δ_{BA}	θ_A	θ_B	δ_{AB}	δ_{BA}	θ_A	θ_B	δ_{AB}	δ_{BA}	θ_A	θ_B
2004	3.61	0.28	0.93	0.07	-0.43	-2.32	0.16	0.84	1.10	0.91	0.55	0.45
2005	0.94	1.06	0.47	0.53	4.43	0.23	0.95	0.05	-0.65	-1.53	0.30	0.70
2006	3.77	0.26	0.93	0.07	5.79	0.17	0.97	0.03	-1.93	-0.52	0.79	0.21
2007	3.39	0.30	0.92	0.08	10.87	0.09	0.99	0.01	24.84	0.04	1.00	0.00
2008	-6.80	-0.15	0.98	0.02	-3.53	-0.28	0.93	0.07	7.70	0.13	0.98	0.02

Data source: calculated by authors

According to data in table 5, we know that the symbiosis mode between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen are all far away from mutualism symbiosis from 2004 to 2008. We use the mean value of $|\theta_A| - 1/2$ of the 5 years to judge in which area the symbiosis mode is more close to mutualism symbiosis, the figure of Beijing is 0.36, the figure of Shanghai is 0.44 and the figure of Shenzhen is 0.30, so the symbiosis mode between venture capital industrial cluster and high-tech industrial cluster of Shenzhen is more close to mutualism symbiosis.

Combining the data in table 5 with formula (5), we could get the Cluster and symbiosis degree between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen (see table 6).

Table 6. Cluster and symbiosis degree between venture capital industrial cluster and high-tech industrial cluster

Year	Cluster and symbiosis degree（Z）		
	Beijing	Shanghai	Shenzhen
2004	0.0395	0.0527	0.1614
2005	0.1066	0.0340	0.1168
2006	0.0569	0.0429	0.0863
2007	0.0733	0.0482	0.0344
2008	0.0585	0.0765	0.0610
Average	0.0670	0.0510	0.0920

Data source: calculated by authors

According to data in table 6, from 2004 to 2008, Shenzhen had the largest cluster and symbiosis degree between venture capital industrial cluster and high-tech industrial cluster, which indicates that the scale of the two industrial clusters and the symbiosis degree matched better than Beijing and Shanghai. Compared with data in table 5, data in table 6 indicates the symbiosis situation between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen more comprehensively.

5. Conclusion

Based on symbiosis theory and principle of system engineering, this paper discussed the symbiosis unit, symbiosis mode and symbiotic environment of industrial clusters, and built a system engineering model of cluster and symbiosis degree which could be used to evaluate the symbiosis situation between two industrial clusters, even carried out an empirical analysis for the symbiosis situation between venture capital industrial cluster and high-tech industrial cluster of Beijing, Shanghai and Shenzhen of China. The result shows that the symbiosis situation of Shenzhen's venture capital industrial cluster and high-tech industrial cluster is much better than that of Beijing and Shanghai. Compared with symbiosis degree model and symbiosis coefficient model, cluster and symbiosis degree model combines symbiosis degree with cluster degree, which can evaluate the symbiosis situation between two industrial clusters comprehensively.

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